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Nutrient and sediment loss from a Niagara County watershed : the east branch of Twelvemile Creek, May 1998 to May 2000

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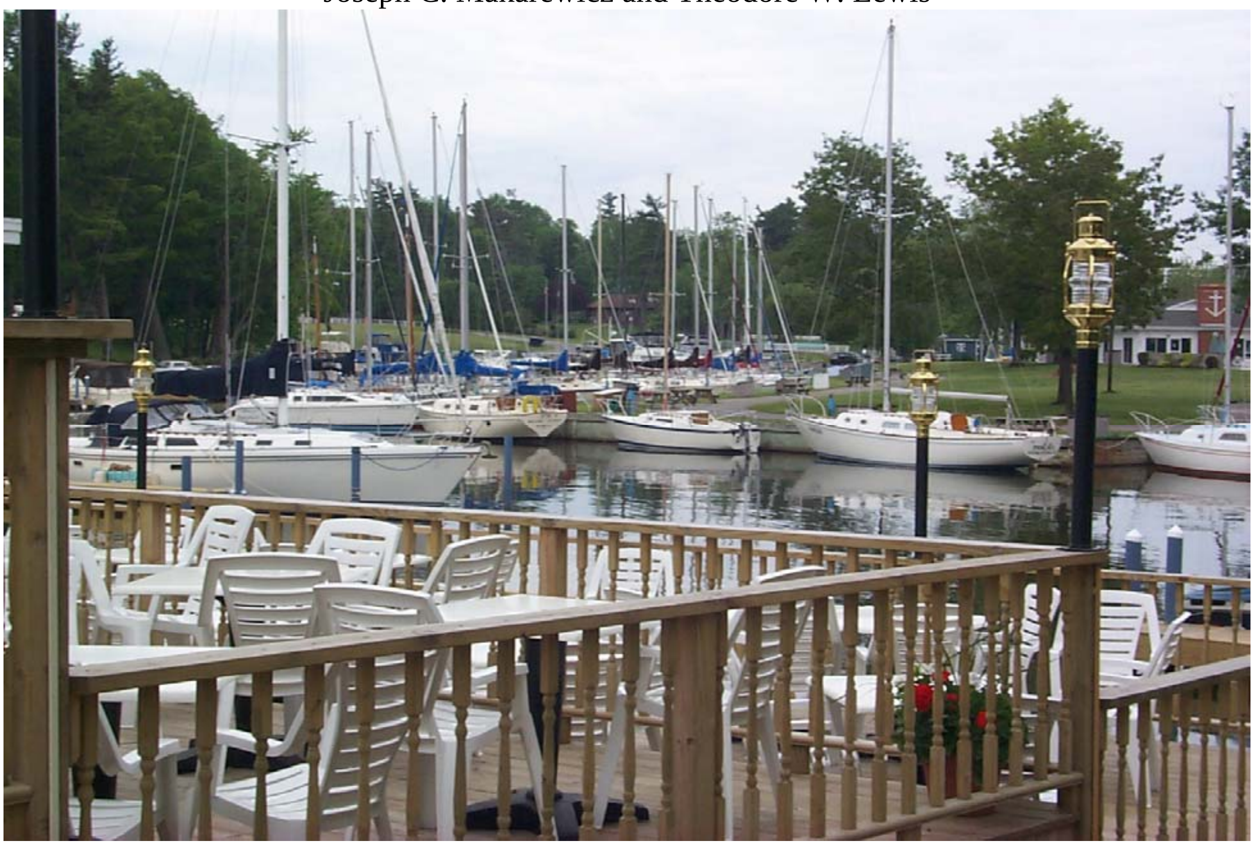

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SUMMARY

- Discharge and nutrient loss from a Niagara County tributary, Twelvemile Creek, was intensely monitored for two consecutive years by automated gauging and sampling techniques. This report focuses on the two annual cycles monitored (19 May 1998 to 18 May 1999 [Year 1] and 19 May 1999 to 17 May 2000 [Year 2]). The sampling regime allows an accurate measurement of discharge, nutrient and soil loss from a watershed during hydrometeorological events and nonevent conditions. Discharge and concentrations of nitrate, total phosphorus, sodium, total suspended solids, and total kjeldahl nitrogen were measured and converted into the amount of material lost from the watershed or loading to Lake Ontario.

- Year 1 annual discharge was very low due to an extremely dry year with prolonged periods where Twelvemile Creek did not flow. Annual precipitation was greater that 7 inches below normal for the annual sampling period. The National Weather Service recorded 31.02 inches of liquid precipitation at its office in Buffalo, NY, during June 1998 to May 1999 (Year 1): a full 7 inches below the normal mean annual precipitation of 38.10 inches. Year 2 (June 1999 to May 2000) annual precipitation was normal at 37.41 inches measured at Buffalo, NY.

- The mean daily discharge values for the dry year of 19 May 1998 to 18 May 1999 (Year 1) period was 13,694 (m^3/day) and for the wetter year of 19 May 1999 to 17 May 2000 (Year 2) period the mean daily discharge value was 31,640 m^3/day. Again these differences in discharge reflect the amount of precipitation for the two years.

- The majority of the water discharged (94%) from the watershed occurred during the winter and spring seasons. The summer season contributed only 0.2% of the total discharge over the two year monitoring period.

- Hydrometeorological events accounted for 29.8% of the annual discharge of Twelvemile Creek during Year 1. In Year 2, the contribution of event discharge increased to 66.7% - a value more typical of western and central New York streams. The disparity in percent of event discharge is due to a decrease in precipitation resulting in an abnormally dry Year 1.

- Concentrations of total phosphorus were relatively low when compared to other streams in western and central New York State. Concentrations of total phosphorus, nitrate, total suspended solids and total Kjeldahl nitrogen were elevated during events suggesting that there are point or non-point sources in the watershed.

- Due to the disparity in the frequency and magnitude of events between sampling years, nutrient losses from Twelvemile Creek were much higher in Year 2 than in Year 1. Total phosphorus was 4.8 times higher, nitrate was 1.4 times higher and TKN was 4.7 times higher in Year 2 than in Year 1. Year 1 was atypical and should not be used as an indicator of conditions within the watershed.

- Total phosphorus was lost from the watershed at a rate of 0.8 kg/d (0.053 g/ha/d) in Year 1 and at a rate of 4.1 kg/d (9.0 lb/d; 0.257 g/ha/d) in Year 2. In Year 1, 88% of the annual

phosphorus loss occurred during the winter, while 60% of the annual phosphorus was lost during events. In contrast, over 90% of the Year 2 phosphorus loss occurred during events, and the annual loss was more evenly distributed across the seasons. The Year 2 results are typical of other watersheds in western and central New York.

- Nitrate loss from the Twelvemile Creek watershed was 34 and 49 kg/d (75 and 108 lb/d) in Year 1 and Year 2, respectively. In Year 1, 43% of the nitrate loss occurred during events, while in Year 2, 65% of the nitrate loss took place during event conditions. Seasonally, nitrate loss from the watershed was greatest during the winter (Year 1- 96%, Year 2- 66%).

- Organic nitrogen measured as total Kjeldahl nitrogen (TKN) was lost at a rate of 6.5 kg/d in Year 1 and 31 kg/d (68 lb/d) in Year 2. Events accounted for 47% of the TKN loss in Year 1 and 78% in Year 2. Greater than 91% of the TKN loss occurred during the combined spring and winter seasons in both years monitored.

- The loss of suspended solids from a watershed is a measurement of loss of soil or erosion from a watershed. The annual loss of soils from the Twelvemile Creek watershed was 219 kg/d in Year 1 and 1,705 kg/d (3,756 lb/d) in Year 2. This is due to the increase in the number and magnitude of events during Year 2. In Year 1, the solids loss was actually greater during baseline conditions versus event conditions. This is highly unusual for watersheds in western and central New York State. Year 2 was more typical, in that greater than 98% of the TSS loss occurred during events.

- Compared to the other watersheds in New York State and based on nutrient and soil loss from the watershed, Twelvemile Creek appears to be minimally polluted by soil and nutrients. It is not as pristine as completely forested watersheds or as polluted as streams receiving direct discharge from a sewage treatment plant. These results are tempered with a fair amount of caution. The two study years were extremely dry, especially the summer, and may not be entirely representative.

RECOMMENDATIONS

- We reluctantly recommend that the intensive tributary monitoring should be continued for another year at Twelvemile Creek. The two years of data represent a strong baseline data set of discharge and loading information but unfortunately the first year of monitoring coincidently occurred during a minor drought. The approach used in this study to evaluate a watershed requires that the stream flows – in other words, has water in it. During the summer and autumn of Year 1, there were long periods of no stream flow compromising our ability to evaluate the loss of soil and nutrients from the watershed. Also, the analysis of the data suffers from a lack of information of the stream at high flow. Currently the rating curve has been split into two different curves – one for high flow and one for lower discharges. More velocity readings at high flows are required. We feel that it is more cost effective to leave the monitoring station at its current location rather than reinstall it at a later time to update the information. We do recognize the pressure to move the monitoring station to another stream to balance out the monitoring effort in the County. However, the current data set is not a fair evaluation of the

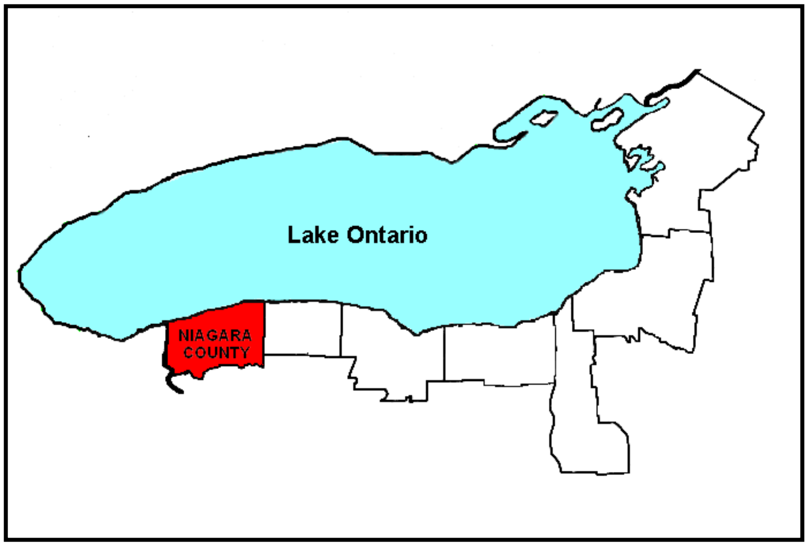
watershed; it is biased to dry years.

- Currently, a Stressed Stream Analysis is being completed for Johnson Creek. This study will identify point and nonpoint sources of nutrients and soil having the largest impact on the quality of the watershed. Once identified, the major sources may be targeted for remediation via Best Management Practices, demonstration projects, changes in zoning, etc. as deemed necessary by the Niagara County Water Quality Coordinating Committee, the Niagara County Soil and Water Conservation District, the Niagara County Health Department, the Niagara County Planning Department or other local governments or agencies that have an interest in improving water quality in the county. The elevated rates of loss of nutrients and soils during hydrometeorological events suggest that segment analysis is necessary to identify sources of "hot spots". We would be more confident of this suggestion after another year of monitoring.

- Stressed stream analysis or segment analysis is a technique that identifies the sources of pollutants within a watershed by subdividing the impacted watershed into small distinct geographical units. Samples are taken at the beginning and end of each stream unit to determine if a nutrient (or other contaminant) source occurs within that reach. We have found this technique very useful in identifying point and non-point sources that are not always obvious. Identified sources can then be targeted for remediation and best management practices.

INTRODUCTION

Freshwater resources have historically played an instrumental role in community development and economic sustainability. Niagara County is not an exception. The water resources in the County play an important role in the economy, have aesthetic value and provide diverse opportunities for those who enjoy the resource directly. A major thrust of the County's tourism industry is predicated on the availability of high quality water resources and angling opportunities in nearshore Lake Ontario and its tributaries. Needless to say, agriculture also has a major economic impact in Niagara County and loss of important resources, such as soil and nutrients, from a watershed is of concern to the land owner and the Soil and Water Conservation District. Remediation and protection of these resources depend largely on the identification of both the cause and effect of elements likely to reduce their economic and social value.



Fishing

From early spring through December, Lake Ontario offers a great diversity of exciting sport and recreational opportunities. Fish in the 20- to 40-pound range are caught by deep trolling from down-rigger equipped boats from vessels launched from harbors in Niagara County. Wilson Harbor (Twelvemile Creek) and Eighteenmile Creek (Olcott) are the headline-grabbing Ontario hot spots with a good share of the honors going to the lower Niagara River where it enters the lake. In fact, surveys show that in 1994, the coast of Lake Ontario from Niagara River to Golden Hill State Park was the most popular fishing area for trout and salmon during the Empire State Lake Ontario Derby. Eighteenmile Creek itself is one of the most popular fishing streams in western Lake Ontario primarily due to major spawning runs for salmon. During a brief four-day fishing derby in May 1994, surveys indicate services supporting the fishing derby earned revenue of 1.3 million dollars - the highest for the seven coastal counties.

Ecological and Historical Importance

Niagara County’s shoreline embayments/drowned river mouths are of ecological and historical importance. Embayments and river creeks are Class I wetlands important for spawning and as nursery areas for fish and birds. A significant coastal wildlife zone also borders Eighteenmile Creek between the Route 18 bridge at Olcott and the dam at Burt. The Niagara River is designated as an Important Bird Area, while Fort Niagara and Golden Hill Creek Lighthouse, as well as Native American sites, are of historical interest to tourist. All the rivers/embayments are the primary spawning sites of forage fish supporting the food base of the Lake Ontario sport

Wilson Harbor at Twelvemile Creek

fishery for salmon and trout.

County Rivers and Creeks

The watersheds of Eighteenmile Creek and Twelvemile Creek have a total drainage of about 93 and 61 square miles, respectively. Most of the land in the basin is relatively flat agricultural and rural residential with most of the industry concentrated in the City of Lockport. Located at the mouth of the Twelve and Eighteenmile Creeks are Wilson and Olcott Harbors – main staging areas for the Niagara County sport fishing industry offering launch and berthing services that serve as the gateway to Lake Ontario for recreational boating and sport fishing. Five marinas and 25 charter boat services for Lake Ontario fishing exist at Olcott and Wilson Harbors. Most of the land bordering Olcott Harbor is occupied by marine-related commercial enterprises with marine docking facilities occupying extensive water areas in the harbor.

The Niagara River is a 38-mile long waterway that connects Lake Erie and Lake Ontario and is the largest river entering Lake Ontario. Before flowing over Niagara Falls and emptying into Lake Ontario, the waters of the Niagara drain about 265,00 square miles encompassing much of the north central United States and south central Canada, including four of the five Great Lakes. Within New York State the river drains about 2,300 square miles. In the Lower Niagara River, 14 charter boat services operate for sport fishing, and two marinas are on the Lower Niagara River. Lower Niagara River serves as a popular sail boating, recreational boating and fishing area, unique and separate from Lake Ontario. The Niagara River serves as a drinking water source, fishing grounds, vacation spot, electricity generator and, in general, generates millions of tourism dollars providing employment for thousands.

County Water Quality Issues

Eighteenmile Creek, with access to Lake Ontario, is the second largest creek in Niagara County. Eighteenmile Creek is polluted by past industrial and municipal discharges, the disposal of waste and the use of pesticides. Fishing is impaired by PCBs and dioxins found in the flesh of various game fish. The health of the benthos is impaired by PCBs and metals in the creek sediments. Bird and animal health is likely impaired by PCBs, dioxins, DDT and its metabolites, and dieldrin found in fish flesh. Contaminated sediments in Eighteenmile Creek, inflow from the past discharge of contaminants into the NYS Barge Canal, and as yet to be determined source of PCBs between Olcott Street and North Transit Road, are certain sources of pollutants. Other sources have been identified as potential sources because the contaminants causing impairments are known to exist, but the link between the source and the impairment has not been clearly

established. Because of these concerns, Eighteenmile Creek has been designated an Area of Concern for which a Remedial Action Plan (RAP) has been developed.

Twelvemile Creek is entirely within Niagara County. Large areas of the north portion of the County are in agriculture and may be losing large amounts of nutrients and soil to Twelvemile and Eighteenmile Creeks causing cultural eutrophication of the embayments.

The water quality at the Niagara River at Fort Niagara has been rated as poor due primarily to the fish consumption advisory and other concerns about impairments to the fishery. However, the slightly impacted macroinvertebrate community and low number of parameters of concern in the water column are more indicative of a fair or even a good rating according to the 1993-94 Biennial Report of the Niagara River-Lake Erie Drainage Basin. The most significant water quality problems in the Niagara River Watershed are related to priority organics contamination from inactive hazardous waste sites and embayments sediments. Analysis of water column samples showed phenolic compounds and lead to be parameters of concern. Because of these concerns, the Niagara River has been designated an Area of Concern for which a Remedial Action Plan (RAP) has been developed.

Under the Niagara River Toxics Management Plan, 18 persistent toxic chemicals or “priority toxics” were identified. As of 1995, the daily loading of the 18 priority toxics has been reduced by 99% in Canada. None of the ten chemicals targeted for 50% reduction was detected at any of the 15 facilities sampled in 1995. On the American side of the River, NYSDEC and EPA estimate a reduction of 80% of the potential inputs into the Niagara River by 1999. Revised remediation call for all of the sites to be completed by 2003 reported an 80% reduction in organic and inorganic priority pollutants from the significant point sources. Estimated cost for remediation is at least $327 million up to 1998.

Water Quality Coordinating Committee

In recognition of the need to acquire a uniform, organized approach to addressing surface water degradation and given the diverse nature of non-point sources of pollution, the Soil and Water Conservation District has formed a committee whose specific task is to address water quality issues. Since the reduction of non-point source pollution is likely to occur through the implementation of Best Management Practices (BMP's) and changes in land use regulations, this committee provides the necessary foundation for these changes to occur. This committee has become known as the Niagara County Water Quality Coordinating Committee (WQCC). With the combined expertise of the Water Quality Coordinating Committee and the availability of actual field data, progress towards healthier freshwater resources is underway. A recommendation of the WQCC was to move forward in prioritizing the major tributaries in terms of high nutrient losses from the watershed.

The objectives of Niagara County's program include:

- Determination of the status of Niagara County's primary surface waters and observe changes over time;
- Documentation of what types and amounts of nutrients may be adversely impacting water quality and the conditions which generate them;

- Determination of what urban, rural, industrial and agricultural practices within a watershed may be impacting water quality;
- Development of a technical database for informed water quality management decisions; and
- Assessment of the feasibility and effectiveness of potential control measures likely to be used to reduce non-point and point sources of pollution.

Determination of sources and magnitude of soil and nutrient losses from a watershed is prerequisite to remedial action and essential to making cost-effective land management decisions as it reduces the likelihood of costly miscalculations based on the assumption of soil and nutrient sources and modeling rather than their actual identification. We have found that this process enhances the ability of concerned groups to obtain external funding for demonstration and remedial projects. As part of the Niagara County water quality program, automated water quality monitoring on Twelvemile Creek was initiated in May of 1998. The two-year data base on Twelvemile Creek represents a strong benchmark of discharge and loading data that can identify potential problems and be used to measure the success of future remediation efforts.

DEFINITIONS

Total Phosphorus- A measure of all forms of the element phosphorus. Phosphorus is an element required for plant growth on land or in water. In lakes, phosphorus is often the limiting factor of phytoplankton growth and is the cause of eutrophication, or overproduction, of lakes. Phosphorus may enter a watershed in soluble or organic form from several sources including sewage, heavy-duty detergents, fertilizer and agricultural waste. Some forms of phosphorus are more available to and cause more immediate activity in plants.

Soluble Reactive Phosphorus- A measure of the most available and active form of phosphorus.

Nitrates + Nitrites- A measure of the soluble forms of nitrogen used readily by plants for growth. Sources of nitrates in the environment are many and include barnyard waste and fertilizer.

Total Kjeldahl Nitrogen- The Kjeldahl method is a convenient method of analysis for nitrogen but cannot be used for all types of nitrogen compounds. It is, however, a good measure of organic nitrogen, including ammonia. Manure, for example, contains a large amount of organic nitrogen.

Sodium- A measure of the mineral, most commonly found as sodium chloride (NaCl), dissolved in water. NaCl naturally occurs in deep layers of local bedrock. Mined, it is stored and spread as a de-icing agent on roads and other pavements.

Total Suspended Solids - A measure of the loss of soil and other materials suspended in the water from a watershed. Water-borne sediments act as an indicator, facilitator and agent of pollution. As an indicator, they add color to the water. As a facilitator, sediments often carry other pollutants, such as nutrients and toxic substances. As an agent, sediments smother organisms and clog pore spaces used by some species for spawning.

METHODS

General:

Personnel from the Niagara County Soil and Water Conservation District collected stream water samples on the east branch of Twelvemile Creek from May 1998 to May 2000. A continuous monitoring station was set up on Youngstown Road in the Village of Wilson (Figure 1). Twelvemile Creek stream levels were monitored continuously with an ISCO flow meter linked to an ISCO sequential sampler which allowed hourly stream sampling during precipitation or runoff events. The rise in the stream level that signified an event and subsequently triggered the automatic sampler was a stream level rise of one inch in a half-hour.

Weekly baseline and event samples were transported to SUNY Brockport for water chemistry analysis for total phosphorus (TP), total Kjeldahl nitrogen (TKN), nitrate + nitrite, sodium and total suspended solids (TSS) (see detailed analytical methods below).

Nutrient and suspended solids losses from the watershed were calculated by multiplying the discharge by the concentration of the nutrient or suspended solids from the appropriate water sample. Stream discharge was manually divided into "baseline" and hydrological "event" conditions (elevated discharge). Event losses from the watershed or loadings to Lake Ontario were calculated using the event chemistry values.

All sampling bottles were pre-coded so as to ensure exact identification of the particular sample. All filtration units and other processing apparatus were cleaned routinely with phosphate-free RBS. Containers were rinsed prior to sample collection with the water being collected. In general, all procedures followed EPA standard methods (EPA 1979) or Standard Methods for the Analysis of Water and Wastewater (APHA 1999). Sample water for dissolved nutrient analysis (nitrate + nitrite) was filtered immediately with 0.45 μm MCI Magma Nylon 66 membrane filters and held at 4°C until analysis.

Water Chemistry

<u>Nitrate</u> <u>+</u> <u>Nitrite:</u> Dissolved nitrate + nitrite nitrogen analyses were performed by the automated (Technicon Autoanalyser) cadmium reduction method (EPA 1979, APHA 1999).
<u>Sodium</u>: Sodium was determined by atomic absorption spectrophotometry (Perkin-Elmer 3030) (APHA 1999).
<u>Total</u> <u>Phosphorus</u>: The persulfate digestion procedure was used prior to analysis by the automated (Technicon autoanalyser) colorimetric ascorbic acid method (APHA 1999).
<u>Total</u> <u>Kjeldahl</u> <u>Nitrogen</u>: Analysis was performed using a modification of the Technicon Industrial Method 329-74W/B. The following modifications were performed:
In the sodium salicylate-sodium nitroprusside solution, sodium nitroferri-cyanide (0.4g) replaced the concentrated nitroprusside stock solution.
The reservoir of the autoanalyser was filled with 0.2M H_2SO_4 instead of distilled water.
Other reagents were made fresh prior to each analysis.
<u>Total</u> <u>Suspended</u> <u>Solids:</u> APHA (1999) Method 2540D was employed for this analysis.

Physical Measurements:

Stream Velocity and Cross-sectional Area: Stream velocity and water depth were measured at 17 equally spaced locations in the cement channel of a bridge over Twelvemile Creek with a Gurley flow meter (Chow 1964). A discharge was calculated for each of the 16 stream segments. The sum of the segment discharges or the total discharge was then related to the stream level reading on the ISCO flow meter. After a range of stream levels had been measured, a polynomial was fit to the values to form the Rating Curve in Figure 2. Figure 2 was constructed with all available data, except the one velocity reading when stream depth was above 2 feet (0.61m). This one velocity reading appeared not to fit the rating curve. We deleted this one point in Figure 2 to provide an accurate discharge reading for stream depths below two feet (0.61m). An additional rating curve was constructed and used for creek levels above 2 feet (0.61m) (Figure 3). More velocity readings are required when water levels are deeper.

Stream Height: Hourly readings of the stream level were measured using an ISCO flow meter equipped with a bubbler sensor. Creek depths, as measured by the flow meters, were manually calibrated weekly.

Watershed Area: The watershed area of Twelvemile Creek was provided by the Niagara County Soil and Water Conservation District. The delineation was performed on topographic maps and quantified by planimetry.

Discharge and Losses from the Watershed (Loading)

Hourly stream level readings (stage height) of Twelvemile Creek were converted to discharge by a second order polynomial rating curve (Figs 2 and 3). For the calculation of nutrient losses from the watershed, event losses were calculated by adding up hourly discharge for both the rising and falling limbs and multiplying them by their respective water chemistry concentrations. During nonevent periods, hourly discharge was summarized into a daily discharge and multiplied by that period's water chemistry concentrations. If a hydrometeorologic event occurred during the week, weekly losses from the watershed were calculated by adding together the event and nonevent losses for the period to obtain total loading to Lake Ontario or total weekly losses from the watershed (event plus nonevent).

Quality Assurance/Internal Quality Control

Multiple sample control charts (APHA 1999) were constructed for each parameter analyzed, except total suspended solids. A prepared quality control solution was placed in the analysis stream for each sampling date. If the control solution was beyond the set limits of the control chart, corrective action was taken and the samples re-run.

External Quality Control: The Water Chemistry Laboratory at SUNY Brockport is certified through the New York State Department of Health's Environmental Laboratory Approval Program (ELAP - # 11439). This program includes biannual proficiency audits, annual inspections and good laboratory practices documentation of all samples, reagents and equipment. Table 1 is a summary of our last proficiency audit.

RESULTS and DISCUSSION

Water Chemistry

Sodium (Table 2):
The average baseline or nonevent concentration of sodium in Twelvemile Creek for the 19 May 1998 to 17 May 2000 (Year 1 and 2) period was 47.43 mg/L (range = 8.28 to 79.43 mg Na/L)). The average event concentration was 36.53 mg/L (11.68 to 79.98 mg Na/L). The average event concentration of sodium did not change significantly from the average nonevent concentrations as the larger volume of water diluted the sodium. Higher values of sodium usually reflect the use of deicing salt in the watershed during the winter and spring seasons.

Total Suspended Solids (Table 2):
Total suspended solid concentrations in stream water generally reflect the amount of materials (e.g., soils) being lost from a watershed. The average total suspended solids concentration was 3.6 mg/L (range = <0.1 to 24.0) for Twelvemile Creek during non-event conditions. Average total suspended solids concentrations increased significantly during events (69.3 mg/L; range = 1.8 to 503.3 mg/L) as the increased water flowing over the watershed carried with it more surficial material.

Total Phosphorus (Table 2):
Phosphorus is an element required for plant growth whether on land or in the water. In lakes, phosphorus is often the limiting factor of phytoplankton growth and is the cause of eutrophication, or overproduction, of lakes. Phosphorus may enter a stream from the watershed as a result of sewage disposal, heavy fertilizer use for lawns or agriculture and through erosion of soil. Watersheds that have streams with high phosphorus concentrations are potentially the cause of increased phytoplankton and macrophyte (weed) production in lakes. Twelvemile Creek had relatively low nonevent concentrations of total phosphorus 44.0 µg P/L (range = 5.2 to 129.8) when compared to other creeks in western and central New York State (Table 3). Total phosphorus concentrations increased significantly during runoff events reaching a maximum concentration of over 1,000 µg/L of phosphorus (mean = 173.5 µg P/L; range = 15.0 to 1022.2 µg P/L).

Nitrate and Total Kjeldahl Nitrogen (TKN) (Table 2):
Nitrate is found in fertilizer, while total Kjeldahl nitrogen roughly represents the organic nitrogen present. Organic nitrogen would occur from sources such as sewage and animal manure. The average baseline concentration of TKN was 610 µg N/L (range=100 to 1,470 µg/L) and increased to 886 µg N/L (range=80 to 2,680 µg/L) during event runoff. Average baseline nitrate concentration in Twelvemile Creek was 0.89 mg N/L (ND to 3.32). The average nitrate concentration nearly doubled during events to 1.69 mg N/L with a maximum concentration reaching 8.52 mg N/L.

Watershed Loss of Materials and Nutrients

Although concentrations provide useful information, the loss from a watershed or loading to Lake Ontario is a better measurement of a watershed's impact because it considers the volume of water in addition to the concentration of the nutrient in that water. A stream with a high concentration of a nutrient but a low discharge will have less of an impact on downstream systems than a stream with high discharge and a moderate concentration of a nutrient.

Tables 4, 5 and 6 present the loss of total phosphorus, total Kjeldahl nitrogen, nitrate, total suspended solids and sodium for the period 19 May 1998 to 17 May 2000 (Year 1 and 2) broken down into individual annual cycles as well as the entire two-year period. The data presented here is based on continuous discharge measurements and thus reflects both high discharge caused by precipitation events and baseflow (nonevent) periods. The event data presented is a result of only those events that were automatically triggered (see methods) by the continuous discharge recorder located on the creeks.

Discharge

The mean daily discharge values for Twelvemile Creek East for the 19 May 1998 to 18 May 1999 period (Year 1) was 13,694 m^3/day and 31,640 m^3/day for the 19 May 1999 to 17 May 2000 period (Year 2) (Tables 4-7, Figure 4). Greater than 92% of the discharge of water from the watershed occurred during the spring and winter seasons (Tables 4-6). Event conditions accounted for only 29.8% of the annual discharge in Year 1 and 66.7% of the annual discharge in Year 2 on Twelvemile Creek (Figure 5). The low event discharge in Year 1 was unusual and was due to the abnormally dry year from May 1998 to May 1999. Annual precipitation was more than 7 inches below normal for the sampling period at the National Weather Service Office in Buffalo, NY. Year 2 (June 1999 to May 2000) annual precipitation was 37.41 inches measured at Buffalo which was slightly below normal (mean annual precipitation = 38.10 inches).

Annual Losses from the Watersheds (Tables 4-7, Figure 5)

<u>Sodium</u>:

Sodium is a major constituent of deicing salt and is often washed off watersheds after application. As expected, major losses of sodium from the watershed occurred during the study period (Tables 4-7). Twelvemile Creek lost 614 kg/d of sodium in Year 1 and 1,409 kg/d in Year 2. Not surprisingly, more sodium was lost from the watershed during the winter and spring seasons - a period of high application of deicing salts to roads (99.4% in Year 1 and 92.9% in Year 2). In Year 1, events accounted for only 24% of the sodium loss while the event loss of sodium during events increased to 63% (Figure 5).

<u>Total</u> <u>Suspended</u> <u>Solids</u> (TSS):

The loss of suspended solids from a watershed is a measurement of loss of soil or erosion from a watershed. The annual loss of soils from the Twelvemile Creek watershed was 291 kg/d in Year 1 and 1,705 kg/d in Year 2 reflecting the difference between a dry and a normal precipitation year. The increase in number and magnitude of precipitation events during a normal relative to a dry year would mean increased volume of water washing over the landscape removing soil and nutrients.

In Year 1, the loss of soil from the watershed was actually greater during baseline conditions than during event conditions. This is highly unusual for watersheds in western and central New York State. Year 2 was more typical, in that greater than 98% of the TSS loss occurred during precipitation events. Seasonally, TSS loss followed the same pattern as discharge. These high losses from the watershed during precipitation events strongly suggest erosive losses from agriculture - although the possibility of bank erosion of streams has not be ruled out.

Nutrients:
Nutrient losses from Twelvemile Creek were much higher in Year 2 than in Year 1 due to the larger amount of water leaving the watershed in Year 2 than in Year 1 – that is, the dry year versus normal precipitation year. Total phosphorus loss from the watershed was 4.8 times higher, nitrate was 1.4 times higher, and TKN was 4.7 times higher in Year 2 than in Year 1.

Total phosphorus was lost from the watershed at a rate of 0.8 kg/d (0.053 g/ha/d) in Year 1 and at a rate of 4.1 kg/d (0.257 g/ha/d) in Year 2 (Table 7). In Year 1, 88% of the annual phosphorus loss occurred during the winter (Table 4), while 60% of the annual phosphorus was lost during events (Fig. 5). In contrast, over 90% of the Year 2 phosphorus loss occurred during events with 50.5% being loss during the winter and 35.6% during the spring (Table 5). High losses of nutrients during the winter and spring are typical of western New York streams.

The nitrate loss from the Twelvemile Creek watershed was 34 and 49 kg/d in Year 1 and Year 2, respectively (Table 7). In Year 1, 43% of the nitrate loss from the watershed occurred during events, while in Year 2, 65% of the nitrate loss took place during event conditions. Seasonally, nitrate loss from the watershed was greatest during the winter (Year 1- 96%, Year 2- 66%).
Organic nitrogen measured as total Kjeldahl nitrogen was lost at a rate of 7 kg/d in Year 1 and 31 kg/d in Year 2. Events accounted for 47% of the TKN loss in Year 1 and 78% in Year 2. Greater than 91% of the TKN loss occurred during the combined spring and winter seasons in both years monitored.

Comparison to Other Watersheds
The various creeks of the Irondequoit Bay watershed (Monroe County, NY.) have been identified as grossly polluted prior to remedial action (O'Brien and Gere 1983). Similarly, Northrup Creek (central Monroe County), which receives effluent from a sewage treatment plant, is known to be polluted and to possess a higher loading of phosphorus than creeks in the Irondequoit Bay watershed (Makarewicz 1988). A comparison of a Niagara County tributary to other creeks in western and central New York State is instructive in identifying the relative condition of this creek (Table 8). Compared to the other watersheds, on an areal basis, Twelvemile Creek is minimally impacted. Loadings are similar to those from forested watersheds. This conclusion has to be viewed with caution because of the abnormally low discharge in Year 1.

However, the high concentrations of nutrients during some events in Twelvemile Creek indicate that point and/or non-point sources of pollution in its watershed do occur. These should be identified and the problems addressed. Segment analysis or stress stream analysis is a process that can identify both point and non-point sources within a watershed.

Best Management Practices

Identified point and non-point sources of nutrients and solids can be remediated using Best Management Practices (BMP). Whether or not management practices include a reduction of cropland or fertilization, control of water movement can be a means of significantly reducing non-point source pollution. Since water must come in contact with the nutrient source and then be transported to the surface (or subsurface) water body, the nutrients in water bodies are functions of soil fertility and quantities of transporting water. Management practices which reduce surface runoff have been shown to decrease dramatically the magnitudes of sediment and chemical losses from land areas (Haith 1975).

Haith (1975) and the NYSDEC (1986) recommend use of buffer strips of forest or grass between the pollutant source and a stream to intercept the runoff, resulting in removal by deposition or filtering by the vegetative cover. Other cropland management practices include diversions, terraces contour cropping, strip cropping, waterways, minimum and no tillage. Livestock operation controls include barnyard runoff management, manure storage facilities and livestock exclusion from woodlands. Urban and rural management applications include critical area stabilization, shoreline protection and settling basins. Urban area best management practices include leaf collection, street sweeping and infiltration systems. The relatively few days of high runoff required to export much of the annual water and nutrients from the Orleans County watersheds implies the necessity of management practices designed to deal with the large volumes of water involved during intense runoff events. Changes in cropping and soil conservation practices, decreases in impervious services, and provision of buffer areas along surface waterways will result in predictable changes in runoff quantities and qualities and hence non-point source pollution (Haith 1975).

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Table 1. Results of the semi-annual New York State Environmental Laboratory Assurance Program (ELAP Lab # 11439, SUNY Brockport) Non-Potable Water Chemistry Proficiency Test, July 1999. Score Definition: 4 (Highest) = Satisfactory, 3 = Marginal, 2 = Poor, 1 = Unsatisfactory.

Analyte	Mean/Target	Result	Score
Solids, Total Suspended	18.3 mg/L	18.2 mg/L	4
Hydrogen Ion (pH)	6.00	5.96	4
Kjeldahl Nitrogen, Total	14.70 mg/L	15.60 mg/L	4
Phosphorus, Total	1.56 mg/L	1.59 mg/L	4
Total Alkalinity Alkalinity	94.60 mg $CaCO_3$/L	98.32 mg $CaCO_3$/L	4
Nitrate (as N)	14.80 mg/L as N	13.33 mg/L as N	4
Orthophosphate (as P)	0.914 mg/L as P	0.920 mg/L as P	4
Chloride	180.0 mg/L	183.2 mg/L	4
Calcium, Total	20.30 mg/L	19.54 mg/L	4
Magnesium, Total	13.00 mg/L	14.22 mg/L	4
Potassium, Total	5.03 mg/L	5.29 mg/L	4
Sodium, Total	35.70 mg/L	36.68 mg/L	4

Table 2. Comparison of baseline and event water chemistry concentrations for the period 19 May 1998 to 17 May 2000 (Year 1 and 2), Twelvemile Creek East. Values are the average ± standard error. The range is in parenthesis. ND = non-detectable.

	Twelvemile Creek East	
	Baseline	Event
Total phosphorus (µg P/L)	44.0 ± 4.2 (5.2 – 129.8)	173.5 ± 18.7 (15.0 - 1022.2)
Nitrate + Nitrite (mg N/L)	0.89 ± 0.16 (ND – 3.32)	1.69 ± 0.22 (ND – 8.52)
Total Suspended Solids (mg/L)	3.6 ± 0.7 (<0.1 – 24.0)	69.3 ± 12.1 (1.8 – 503.3)
Total Kjeldahl Nitrogen (µg N/L)	610 ± 40 (100 – 1470)	886 ± 47 (80 – 2680)
Sodium (mg/L)	47.43 ± 2.35 (8.28 – 79.43)	36.53 ± 1.88 (11.68 – 79.98)
Watershed area (ha)	15,799	

Table 3. Nonevent (baseline) total phosphorus concentrations and watershed areas from creeks in central and western New York. Data is from Makarewicz 1988, Makarewicz and Lewis 1992, 1996, 1998, 1998a, 1999, Makarewicz *et al*.1991.

Creek	Total phosphorus (µg P/L)	Watershed Area (ha)	Land Use
Canandaigua Lake Watershed 1997			
Fall Brook	19.4	1343	Agriculture /suburban
Deep Run Gully	7.4	525	Agriculture
Vine Valley	28.4	1115	Agriculture
Clark Gully	9.1	325	Forested
Naples Creek	5.5	8143	Agriculture / Suburban
Sucker Brook	97.5	1759	Urban / Agriculture
Seneca Point	94.8	1048	
Oswego County 1997			
Sheldon	92.0	1357	Muckland
Summerville	108.1	409	Suburban
Ley	270.8	632	Muckland / Agriculture
Wayne County 1991-92			
Sodus	46.3	3065	Agriculture
Wolcott	115.6	4416	Agriculture
Second	31.3	2610	
Orleans County 1997-98			
Oak Orchard	126.4	36989	Agriculture
Johnson	88.3	25530	Agriculture
Sandy	96.9	23056	Agriculture / Suburban
Orleans County 1998-99			
Oak Orchard	103.5	36989	Agriculture
Johnson	95.8	25530	Agriculture
Sandy	123.7	23056	Agriculture / Suburban
Seneca County 1990-94			
Kendig	143.0	5149	Agriculture
Livingston County 1990-91			
Hanna's	74.6	718	Agriculture / Suburban
Conesus Inlet	28.2	4475	Wetlands / Agriculture
South McMillan	30.6	2687	Agriculture
Monroe County 1987-88			
Upper Northrup	68.6	1049	Suburban
Lower Northrup	263.6	1862	Suburban / Sewage Plant
Niagara County 1998 - 2000			
Twelvemile Creek	44.0	15799	Agriculture / Suburban

Table 4. Annual loss of material and nutrients from the Twelvemile Creek watershed, 19 May 1998 to 18 May 1999 (Year 1). TP = total phosphorus, TSS = total suspended solids, TKN = total Kjeldahl nitrogen.

	Discharge m^3	TP kg	Nitrate kg	Sodium kg	TSS kg	TKN kg
Spring	1,149,400	33	485	53,427	3,405	540
Summer	20,455	4	16	645	1,828	21
Fall	13,784	1	1	561	210	8
Winter	3,814,516	270	11,943	169,380	100,842	1,807
% Spring	23.0	10.6	3.9	23.8	3.2	22.7
%Summer	0.4	1.3	0.1	0.3	1.7	0.9
%Fall	0.3	0.4	0.0	0.3	0.2	0.3
%Winter	76.3	87.7	96.0	75.6	94.9	76.0

Table 5. Annual loss of material and nutrients from the Twelvemile Creek watershed, 19 May 1999 to 17 May 2000 (Year 2). TP = total phosphorus, TSS = total suspended solids, TKN = total Kjeldahl nitrogen.

	Discharge m^3	TP kg	Nitrate kg	Sodium kg	TSS kg	TKN kg
Spring	5,797,904	528	3,777	258,208	192,837	5,648
Summer	9,946	1	2	316	106	6
Fall	889,098	204	2,380	36,194	59,010	934
Winter	4,851,725	749	11,838	219,690	370,302	4,594
% Spring	50.2	35.6	21.0	50.2	31.0	50.5
%Summer	0.1	0.04	0.01	0.1	0.05	0.1
%Fall	7.7	13.8	13.2	7.0	9.5	8.4
%Winter	42.0	50.5	65.8	42.7	59.5	41.1

Table 6. Total loss of material and nutrients from the Twelvemile Creek watershed, 19 May 1998 to 17 May 2000 (Year 1 and 2). TP = total phosphorus, TSS = total suspended solids, TKN = total Kjeldahl nitrogen.

	Discharge M^3	TP kg	Nitrate kg	Sodium kg	TSS kg	TKN kg
Spring	6,947,305	560	4,261	311,635	196,242	6,188
Summer	30,401	5	18	960	1,934	27
Fall	902,882	205	2,381	36,754	59,219	942
Winter	8,666,241	1,019	23,781	389,070	471,144	6,401
% Spring	42.0	31.3	14.0	42.2	26.9	45.6
%Summer	0.2	0.3	0.1	0.1	0.3	0.2
%Fall	5.5	11.5	7.8	5.0	8.1	6.9
%Winter	52.4	56.9	78.1	52.7	64.7	47.2

Table 7. Average daily loss of material and nutrients from the Twelvemile Creek watershed for Year 1 (19 May 1998 to 18 May 1999), Year 2 (19 May 1999 to 17 May 2000) and the period 19 May 1998 to 17 May 2000 (Year 1 and 2). TP = total phosphorus, TSS = total suspended solids, TKN = total Kjeldahl nitrogen.

	Discharge m^3/day	TP kg/day	Nitrate kg/day	Sodium kg/day	TSS kg/day	TKN kg/day
Year 1	13,694	0.8	34	614	291	7
Year 2	31,640	4.1	49	1,409	1,705	31
Year 1 and Year 2	22,667	2.5	42	1,012	998	19

Table 8. Comparison of phosphorus loading in subbasins of the Irondequoit Bay watershed, other Monroe County creeks, tributaries of Sodus and Port Bays, and Lake Neatahwanta tributaries. Irondequoit basin data are from 1980-81 (O'Brien and Gere 1983). Data from other Monroe County creeks are from 1987-88 (Makarewicz 1988). Wayne County creek data from 1991-93 are from Makarewicz et al. 1991, 1992, 1993, 1998 and 1998a, Makarewicz and Lewis 1998, 1999. All data is for an annual period (i.e., mean annual daily loading).

Subbasin or Creek	Land Use	Total Phosphorus Loading Annual Daily Average (g P/ha/d)	
Sucker Brook	Agriculture/Urban	7.66	
Irondequoit Creek at Browncroft Blvd. 1975-77 (pre-diversion)	Several Sewage Plants	5.60	
1978-79 (post-diversion)		2.00	
Larkin	Suburban	0.70	
Buttonwood	Suburban	1.58	
Lower Northrup	Sewage Plant	6.64	
Upper Northrup	Urban	3.23	
First	Forested	0.11	
Clark	Forested	0.22	
Sodus East	Agriculture	8.57	
Wolcott	Agriculture	5.01	
Bobolink	Forested	0.02	
Sheldon	Muckland	27.41	
Summerville	Suburban	5.47	
		1997-98	1998-99
Oak Orchard		3.48	2.86
Johnson		1.81	1.17
Sandy		0.98	0.77
		1998-99	1999-00
Twelvemile Creek East	Agriculture	0.5	0.26

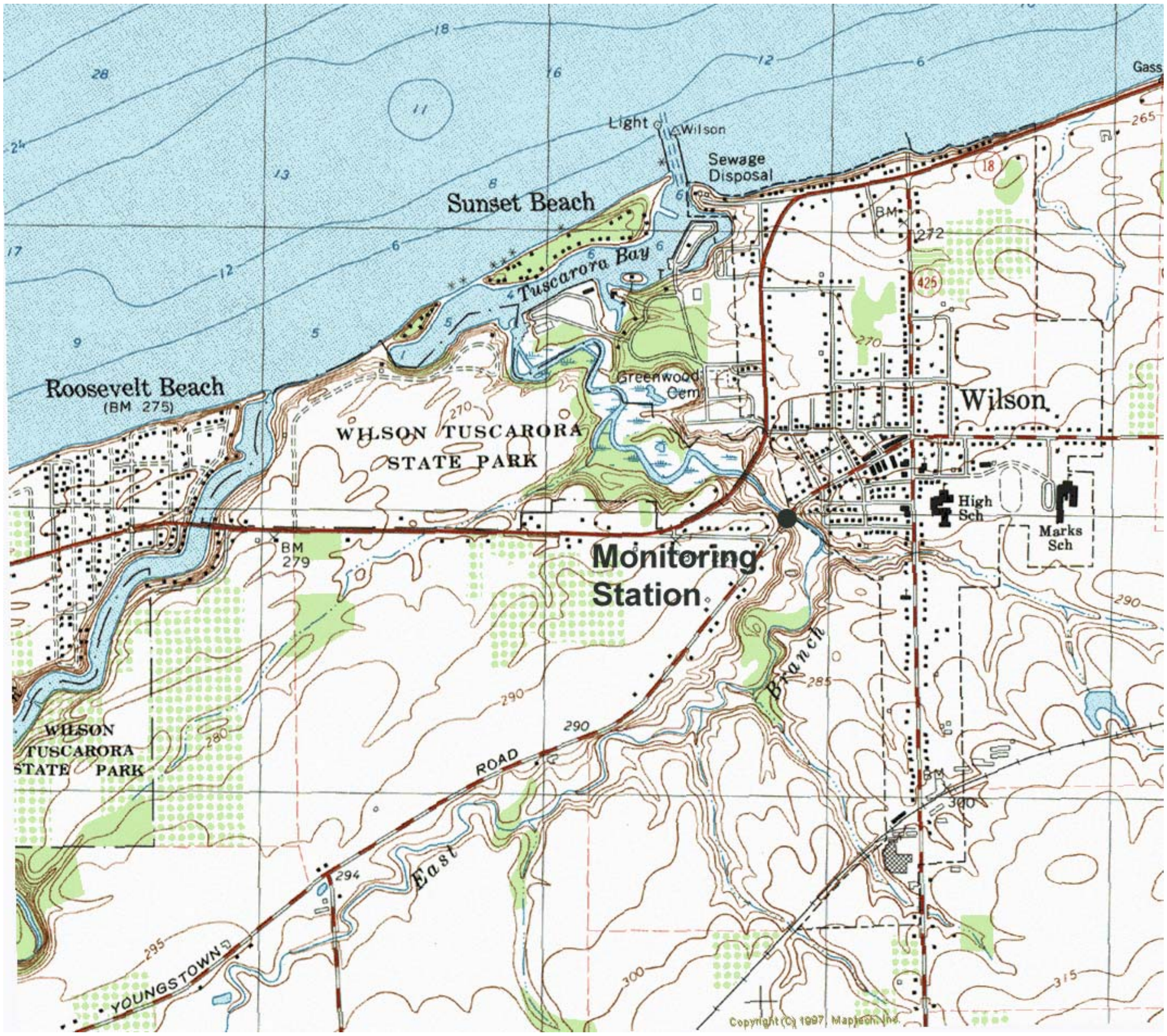


Figure 1. Map of Twelvemile Creek East showing the location of the monitoring station on Youngstown Road in the Village of Wilson, NY.

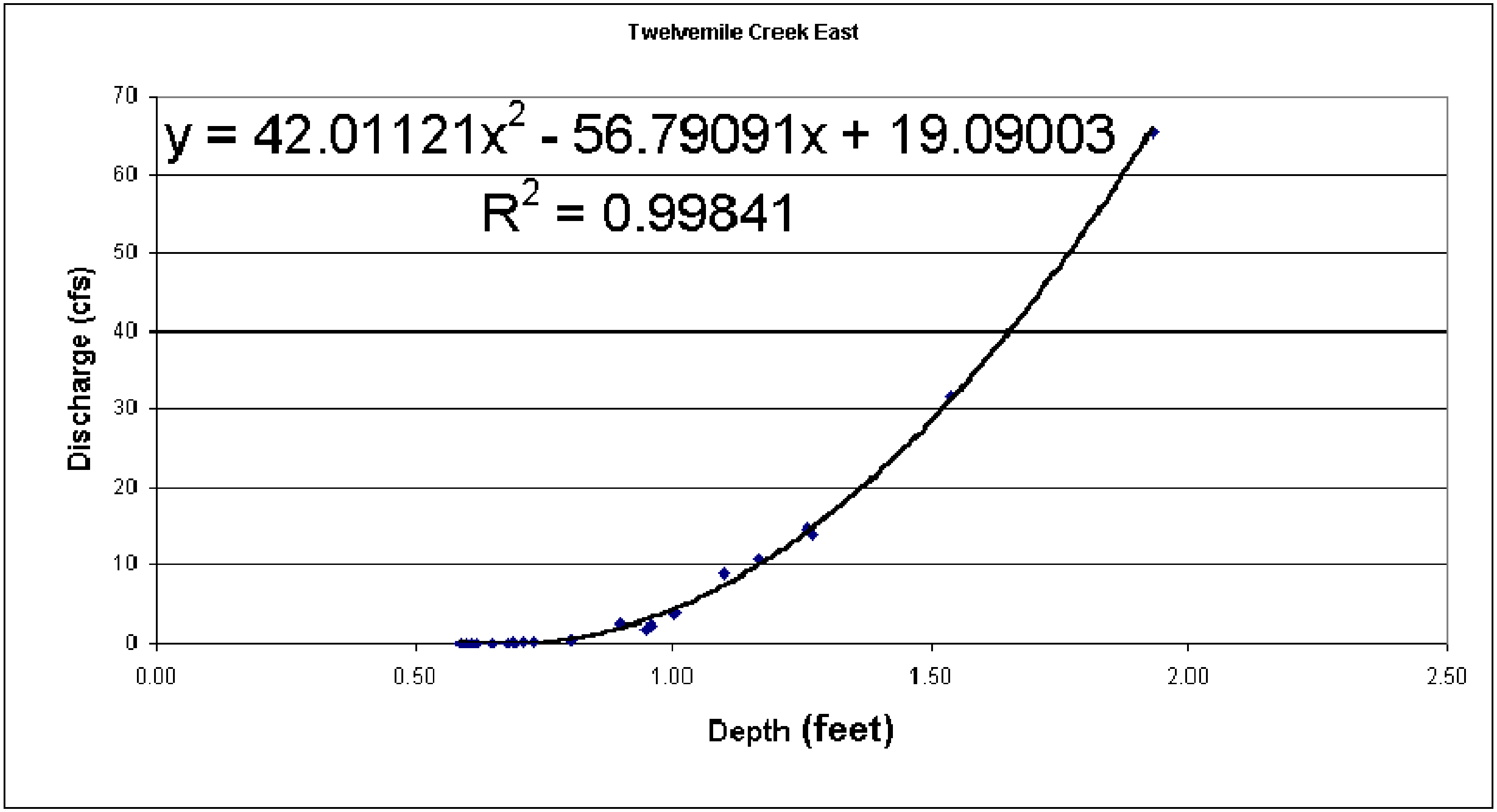


Figure 2. Rating curve for Twelvemile Creek East to be used for creek depths less than 2 feet.

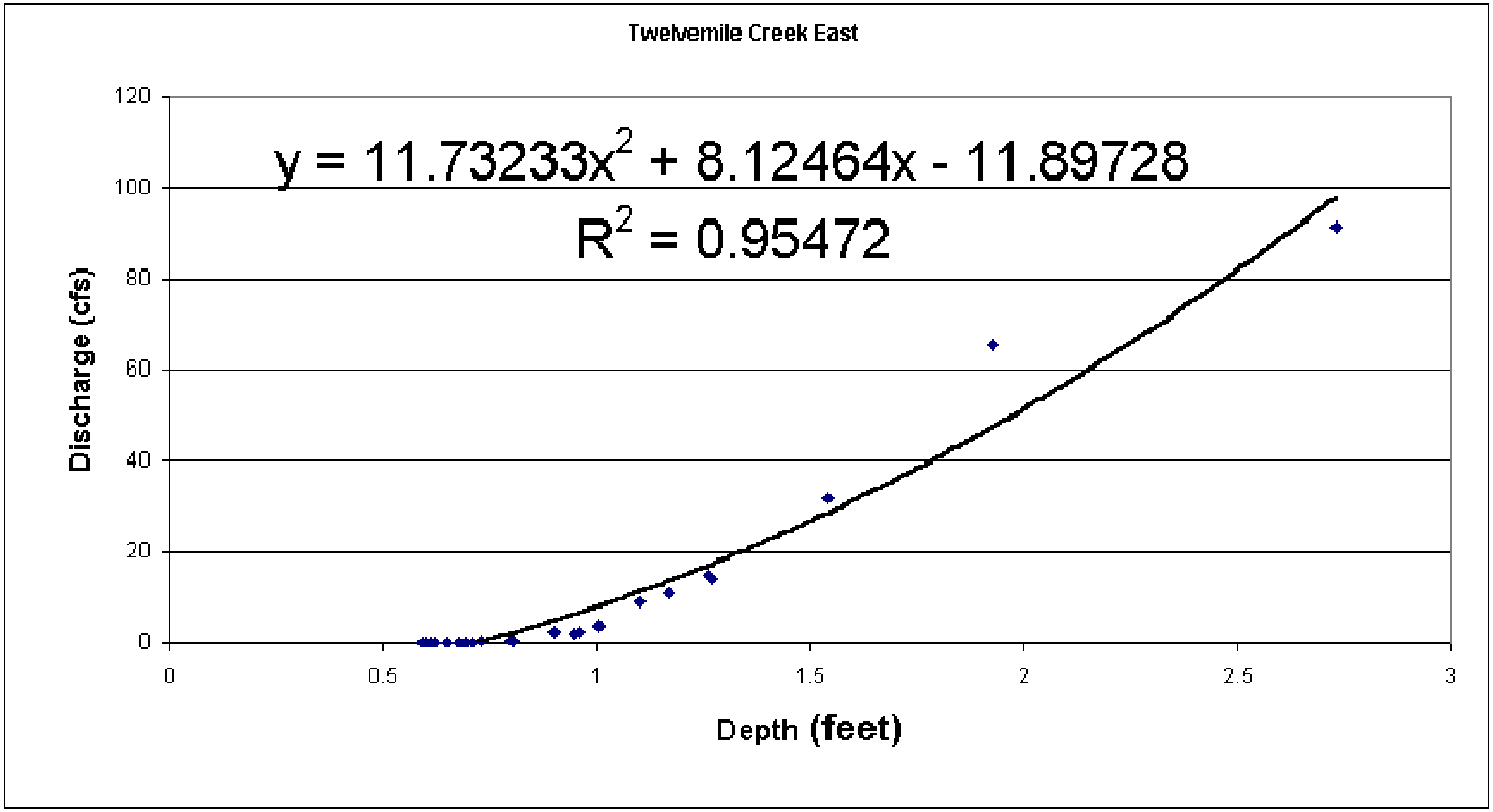


Figure 3. Rating curve for Twelvemile Creek East to be used for creek depths 2 feet or higher.

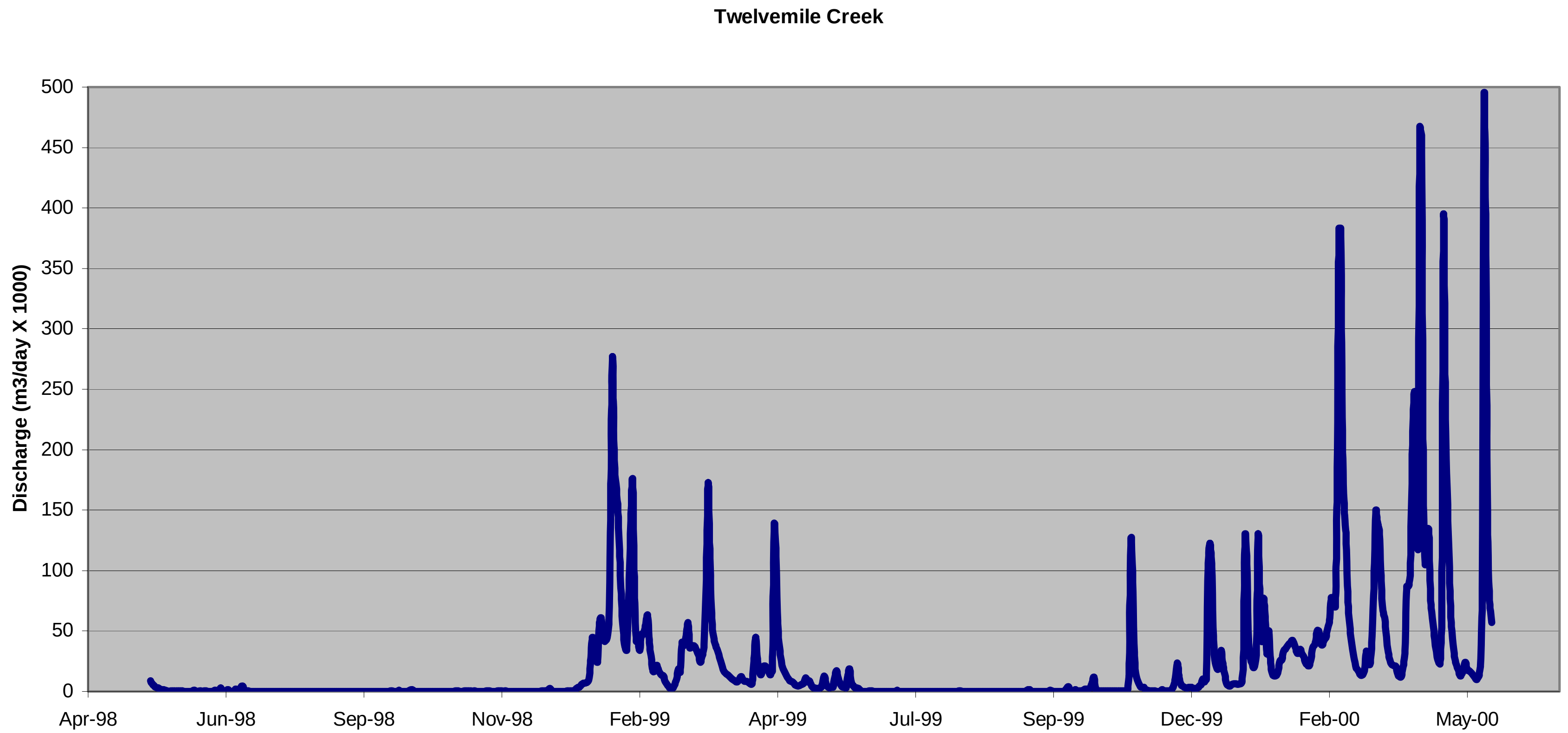
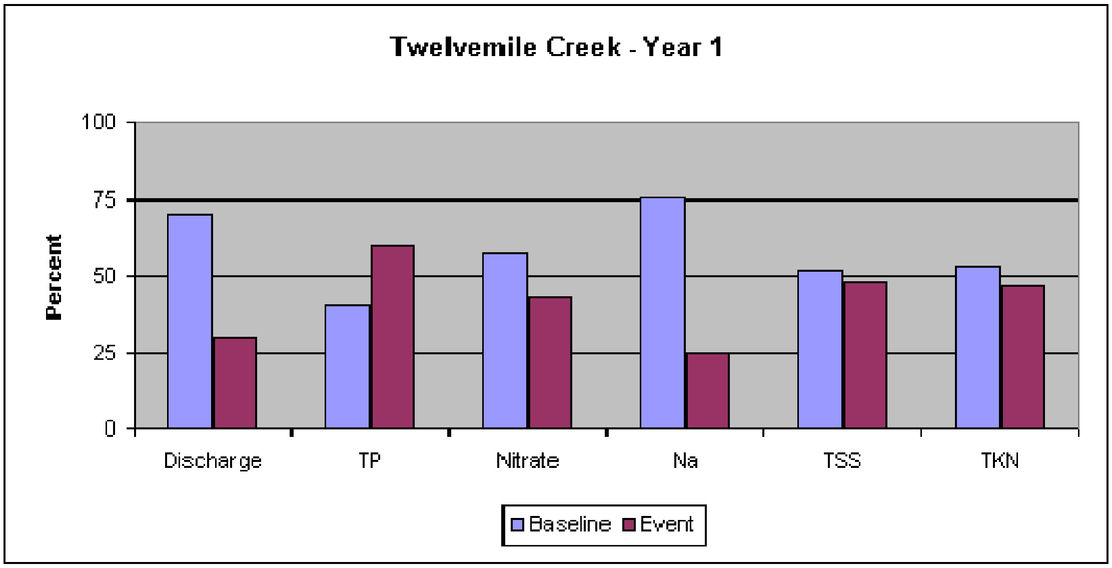


Figure 4. Discharge for Twelvemile Creek East for the period 19 May 1998 to 17 May 2000 recorded at the automated monitoring station located on Youngstown Road in the Village of Wilson, NY.



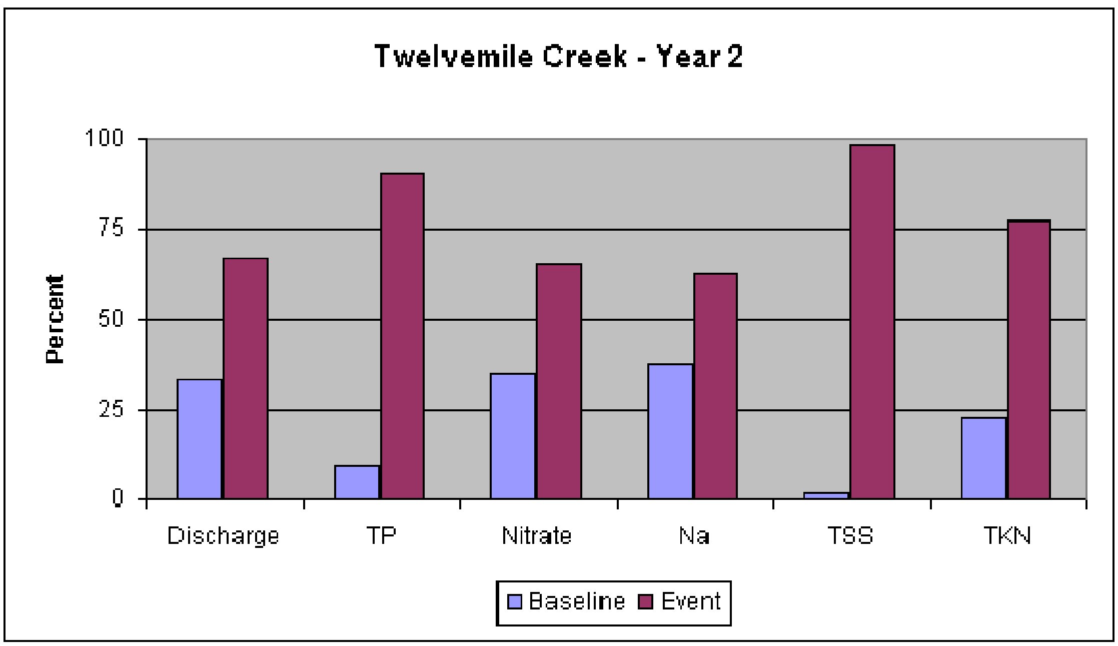


Figure 5. Percent baseline and event discharge and percent total phosphorus (TP), nitrate, sodium (Na), total suspended solids (TSS) and total Kjeldahl nitrogen (TKN) loss from Twelvemile Creek for the period 19 May 1998 to 17 May 2000.